Guide to Reporting on Common Indicators Used in State of the Watershed Reports

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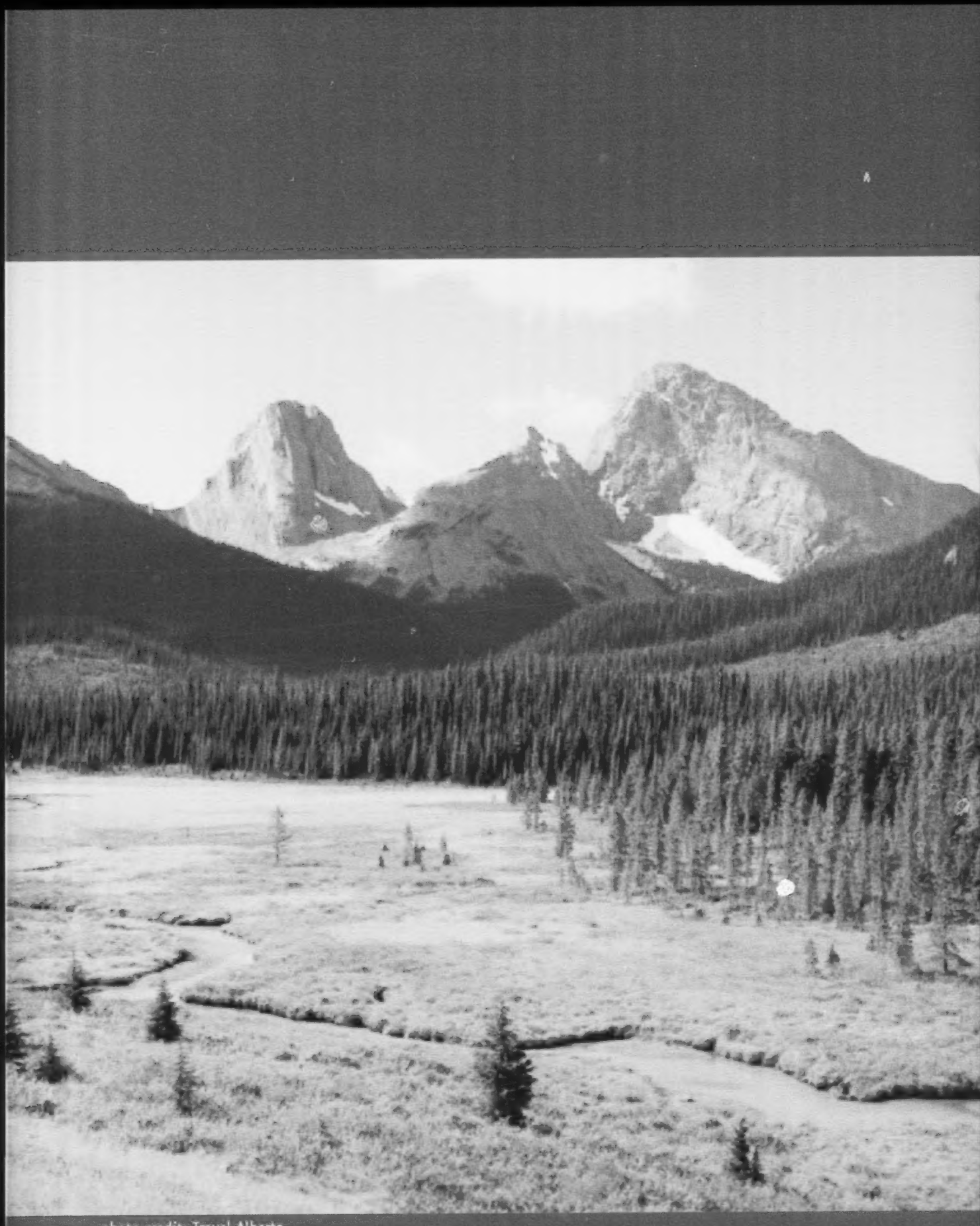
Alberta Environment and
Sustainable Resource Development

water for life

Alberta Government



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Preface

The *Guide to Reporting on Common Indicators Used in State of the Watershed Reports* is a companion document to the *Handbook for State of the Watershed Reporting: a Guide for Developing State of the Watershed Reports* in Alberta released by in 2008.

The establishment of a suite of core indicators of watershed health was identified as a recommendation by the Alberta Water Council in their 2008 report, *Recommendations for a Watershed Management Planning Framework for Alberta*, and more recently as a key action of the Government of Alberta in the *Water for Life Action Plan* (2009). This guide, however, takes the approach that the indicators identified here are not a prescriptive suite of essential indicators, but a subset of more conventional indicators from which to build a comprehensive assessment of the overall health of a watershed. Consistent reporting of common indicators will enable other stakeholders and authorities to effectively compare and incorporate the information and findings of watershed assessments with other work.

The main audience for this document includes Alberta's Watershed Stewardship Groups and Watershed Planning and Advisory Councils. It was written with their input and the input of Government of Alberta staff.

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1.0 Introduction to the Guide

1.1 Purpose and Limitations of the Guide to Reporting on Common Indicators Used in State of the Watershed Reports

Despite an increasing number of state of the watershed (SoW) reports being generated by Alberta's watershed community, there has been little communication and sharing of approaches on the selection of indicators and reporting formats considered in these reports. Consequently, the result has been a patchwork of watershed health indicators, indices, and rating systems.

The objective of the *Guide to Reporting on Common Indicators Used in State of the Watershed Reports* is to provide criteria and direction to establish consistent reporting for a subset of more conventional watershed health indicators commonly found in state of the watershed reports, and recognized as being applicable in most watersheds. The indicators presented in this guide are *not* intended to limit the number of indicators incorporated into a state of the watershed report, nor the assemblage of indicators to be included in these reports. That remains a decision for the author of the report to determine.

As a companion document to the *Handbook for State of the Watershed Reporting: A Guide for Developing State of the Watershed Reports in Alberta*, released in 2008, this guide is intended to serve as a reference for groups reporting on these more common indicators, and does not prescribe a standard suite of indicators to be applied across all watersheds. Although some indicators may be similar, the guide does not prescribe indicators for undertaking regional strategic assessments, nor for measuring cumulative effects management as set out in *Alberta's Land-use Framework* (2008). Going forward, the alignment of state of watershed indicators with those used in other environmental reporting and planning initiatives would facilitate the integration of these works, and contribute to the recognition of stakeholder-led watershed assessments and watershed planning as legitimate tools in the resource management toolbox.

Admittedly, the development and acceptance of an overall suite of indicators and associated rating system requires further refinement; this guide, in its current format, encourages consistency rather than standardization in state of the watershed reporting in Alberta.

1.2 Intended Users of the Guide to Reporting on Common Indicators used in State of the Watershed Reports

The primary audience for this guide includes the province's Watershed Planning and Advisory Councils (WPACs) and community-based Watershed Stewardship Groups (WSGs) pursuing state of the watershed reporting initiatives in Alberta. The information and guidance described in the guide will also be useful to government and agency representatives, consultants, researchers and academics, and other stakeholder groups participating in, or providing information, advice, or technical support to these initiatives.

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2.0 Common Indicators Used in State of the Watershed Reports

2.1 What is Meant by Common Indicators?

As described in the *Handbook for State of the Watershed Reporting* (2008), an indicator refers to an easily measurable attribute that reflects one aspect of the underlying condition or state of the broader system. In this case, we are referring to indicators of watershed health.

All state of the watershed reporting initiatives will include an assessment of a number of select environmental indicators (condition, pressure, response, and perhaps performance indicators) that individually and collectively paint a picture of a watershed's overall environmental health. Although issues, conditions and pressures vary across watersheds necessitating reporting on a variety of different indicators in each watershed, state of the watershed reports typically contain a shared subset of indicators that are commonly (but not necessarily consistently) reported on, regardless of the watershed's location or scale. In this guide, the designation of these as common indicators refers to the broader application of the indicator and is not a reflection of the importance of that indicator for state of the watershed reporting.

2.2 Why Single Out These Indicators?

In recent years, watershed-based organizations across Alberta have actively pursued a variety of different methods of reporting on conditions within their respective watersheds, ranging from simplified report cards, to printed status reports, to living web-based compilations of data. Regardless of the format, these reports have proven to be invaluable sources of information to resource managers, decision-makers, and local stewards. State of the watershed reporting provides an overview of current and baseline conditions from which performance and the success of stewardship and management actions can be measured in the future.

Along with general information on a watershed's physical geography and history of development, state of the watershed reports typically include information on a variety of both universal and watershed-specific parameters. Unfortunately, to date, there exists no guidance in Alberta on the selection of indicators for inclusion, and little or no consistency in the manner in which those indicators common to many reports are reported on.

For example, consider nutrient levels — one of the most familiar indicators of water quality. In a state of watershed report, does one report on nutrient concentrations in relation to Alberta's Surface Water Quality Guidelines, according to Canadian Council for the Minister's of the Environment (CCME) Water Quality Guidelines, or according to local objectives? Or perhaps,

simply as a numeric value with no reference to any existing guidelines or objectives? Does one report on each parameter (or metric) individually, or within a multi-metric index? If the latter, which index should be used? Alberta Environment and Sustainable Resource Development's overarching Surface Water Quality Index, the Nutrient Sub-index, or perhaps Alberta Agriculture & Rural Development's Water Quality Index for Agricultural Streams? Each differs and the subsequent values generated within each index are not comparable. Furthermore, for many indicators, there simply is no standard rating system to convey overall conditions making it difficult to assess and communicate the current state of a specific parameter.

The absence of a consistent reporting framework creates a situation where for each parameter, organizations undertaking state of the watershed reports are either required to develop their own rating systems, choose arbitrarily from existing rating systems, or simply report on the indicator in a purely quantitative manner without tying the data to any rating system. The reality to date is that depending upon which state of the watershed report you may be reading, any of these reporting formats may be used. The use of different indices and rating systems for the same parameter limits the usage of these assessments by making it impossible to directly compare the results between watersheds, and/or roll up information from sub-watersheds to provide a collective representation of conditions within a larger watershed or region.

The indicators referred to in this guide as common indicators represent but a subset of traditional indicators for which Alberta Environment and Sustainable Resource Development is looking to establish some consistency and criteria for the manner in which these indicators are reported on. Building upon this base, watershed groups are encouraged to include any number of other relevant indicators needed to illustrate the overall condition of one's watershed. The final list of indicators incorporated into any state of the watershed report should be tailored to the site-specific issues and opportunities in each watershed and to the desired outcomes established for that watershed.

2.3 What are the Common Indicators Used in State of the Watershed Reports?

Indicators selected for inclusion in a state of watershed report should be those most relevant to the issues, concerns, and opportunities within a specific watershed. In selecting indicators on which to report, groups should refer to the extensive list of examples of indicators and metrics outlined in the *Handbook for State of the Watershed Reporting* (2008).

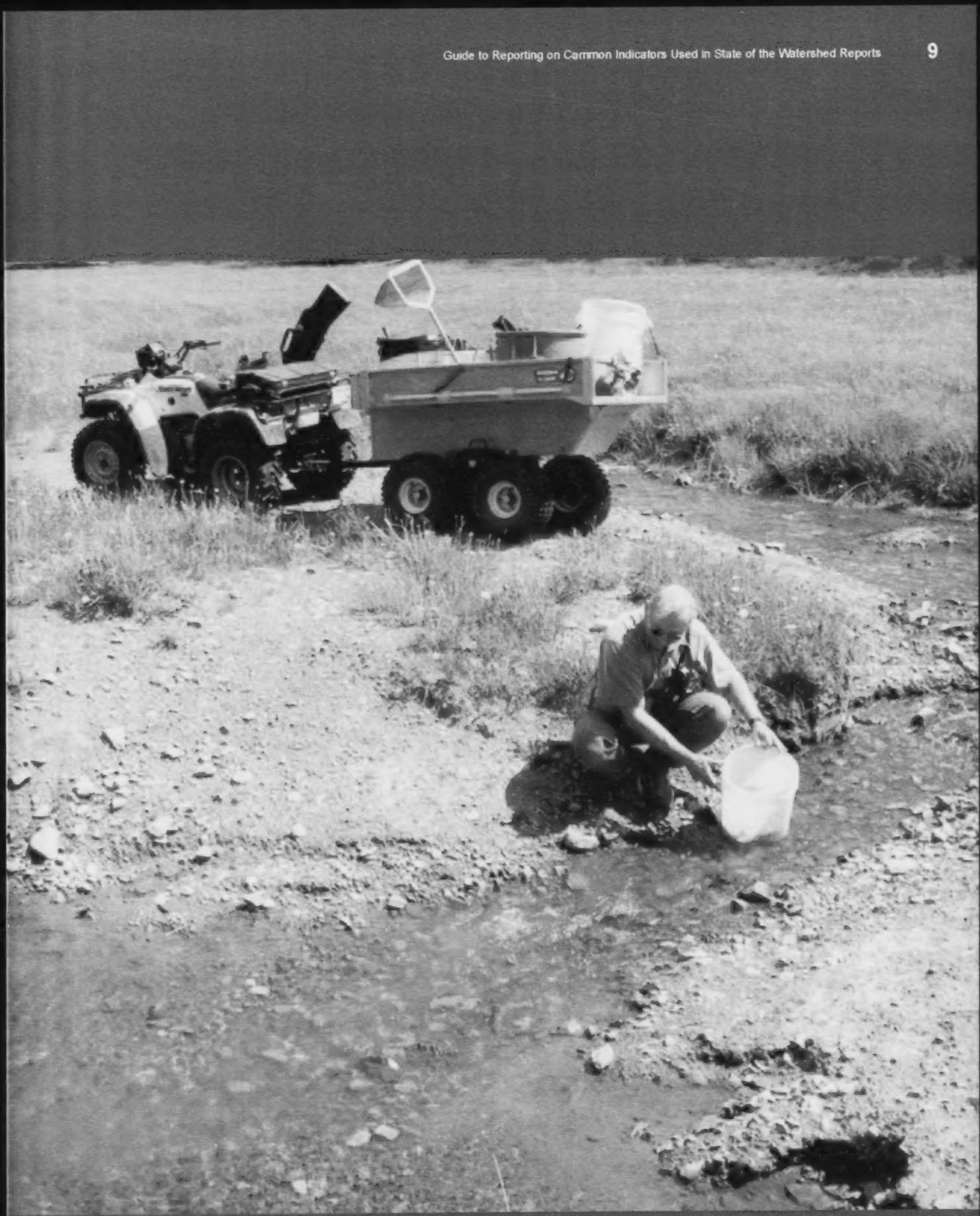
The availability of data, the applicability of the indicator at various scales of watershed, and its contribution to providing a basic understanding of watershed health were key considerations in selecting the common indicators to be included here. The process included a review of existing state of the watershed reports in Alberta and in other jurisdictions for the indicators being reported on. Discussions with government staff and representatives from Alberta's watershed planning and reporting community assisted in identifying those indicator categories considered to be both more widely used and informative, as well as those needing clarification in terms of how best to be reported on. Subsequent discussions with government staff with expertise in the identified indicator categories led to recommendations for the most appropriate indicators and formats for reporting on these. The guide also includes several not-as-common indicators being promoted for use in state of watershed reporting because of their applicability to contribute to higher level assessments and/or potential planning initiatives. In most cases, these indicators are not new and are already being extensively reported on by various groups and/or agencies throughout the province.

Listed in Section 3.0 under their respective indicator category, common indicators currently being recommended for consideration in state of the watershed reporting include:

- Nutrient concentrations;
- Bacteria concentrations;
- Surface water allocations;
- Variation of annual flow and/or lake levels;
- Flow commitments;
- Groundwater allocations;
- Groundwater well density;
- Land use/land cover;
- Riparian health; and
- Biotic integrity.

Indicators should, wherever possible, be evaluated and selected according to adherence to existing guidelines, thresholds or targets, or deviation from historic averages and trends.

Continual adjustments, refinements, and revisions either to individual indicators or the list as a whole are anticipated. The suite of common indicators suggested here may be amended over time.



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3.0 Reporting on Common Indicators

3.1 Surface Water Quality

Many factors influence surface water quality, including climate and precipitation events, soil type, geology, vegetation, groundwater and flow conditions, and, of course, human activities. For this reason, there is no single or simple measure of water quality. Water may be tested for few or many parameters depending on the need and the question that one is trying to answer.

Typically, water quality indicators fall into three broad categories:

- **Physical characteristics,** such as temperature, colour, suspended solids and turbidity;
- **Chemical characteristics,** such as nutrients, minerals, metals, oxygen, pesticides, hydrocarbons, pharmaceuticals, PCBs, and other parameters; and,
- **Biological characteristics,** such as the types and quantities of bacteria, protozoan parasites, algae, invertebrates, plants and other animals.

Physical, chemical, and biological indicators may be reported on separately or in combination to describe the overall quality or health of aquatic ecosystems. This is the premise behind the *Alberta River Water Quality Index (ARWQI)*.

The Alberta River Water Quality Index actually consists of four sub-indices calculated annually for four variable groups (metals, nutrients, bacteria, and pesticides) and then combines these values into a single descriptor of water quality. However, in many watersheds the full suite of information needed to calculate an Alberta River Water Quality Index value may not be available. Furthermore, this index has been modified for use in different basins, and in each case may be based on a different subset of parameters and/or water quality objectives. For these reasons, the Alberta River Water Quality Index may not be applicable in all watersheds. It may be more appropriate to report on water quality conditions using the individual sub-indices, or at least those most relevant to the issue(s) and desired outcomes within the selected watershed. The following subsections provide further information on two common indicators and their associated indices.

3.1.1 Nutrient Concentrations

Nutrient concentrations are a common water quality condition indicator because this indicator reflects a water body's ability to promote excessive growth of algae and aquatic macrophytes (which in addition to being a nuisance can lead to reduced dissolved oxygen levels and/or the release of toxins). For this reason, many authorities, including Alberta Environment and Sustainable Resource Development, have established water quality guidelines for individual nutrients and associated tools to assist reporting.

Single Metric Indicators

As phosphorus and nitrogen have traditionally been identified as the primary nutrients of interest, further discussion of nutrient concentration will focus specifically on these two metrics. According to the *Surface Water Quality Guidelines for Use in Alberta* (Alberta Environment, 1999), the following have been established as the "Water Quality Guidelines for the Protection of Freshwater Aquatic Life", and are typically used as the provincial standard:

Nitrogen (total inorganic and organic)	1.0 mg/L
Phosphorus (total inorganic and organic)	0.05 mg/L

These guidelines are meant to provide general guidance in evaluating surface water quality throughout Alberta.

It should also be recognized that although guideline values for these and many other water quality indicators have been set either in Alberta or other jurisdictions, they may not be appropriate across all watersheds. This is because guidelines are generic in the sense that they are intended to be applied to any surface water body and do not take into account natural variability, variability due to differences in water body types, local species composition and species sensitivities, or the synergistic, antagonistic, and/or cumulative effect of contaminant mixtures. In some cases, provincial guidelines may be under or over-protective because particular aquatic species at a given site may differ in sensitivity from those used for the development of the generic guideline.

For example, in pristine headwater reaches, more conservative and protective objectives than what is currently set by the provincial guidelines may be needed, while in downstream prairie reaches, more lenient and permissive objectives may be more applicable because provincial guidelines may be exceeded under natural conditions. Ultimately, reach-specific or region-specific water quality objectives can be developed. Regional planning and environmental management frameworks are examples of

mechanisms whereby this occurs. In the absence of approved reach or water body-specific objectives, any assessment of nutrient concentrations within Alberta's watersheds should be reported against provincial water quality guidelines.

Some watershed organizations have further characterized monitoring results according to subjective categories (e.g., high/medium/low), or have attached value statements (e.g., good/fair/poor) to specific nutrient concentrations. It should be noted, that for the reasons outlined above, no such rating system has been endorsed by the Government of Alberta. As an alternative, groups looking to categorize nutrient monitoring results may consider a rating system based on the number of times that recorded measurements over a one year period "exceed" the provincial guidelines or water quality objectives established for that indicator at that location. For example:

GOOD	0% – 10% of recorded measurements exceed the guideline
FAIR	10 – 50% of recorded measurements exceed the guideline
POOR	> 50% of recorded measurements exceed the guideline

This concept is similar to that used in calculating index scores using the Alberta River Water Quality Index, although it considers only a single variable, and does not take into account by how much the measured concentrations exceed the objective. The representativeness of the calculated rating will be a reflection of the number of monitoring events and the conditions at that time. For this reason, monitoring programs should be designed to capture the range of conditions throughout the year.

River Nutrient Index — Larger Rivers Only

Alberta Environment and Sustainable Resource Development developed a composite multi-metric index of nutrient conditions that rates water quality as "Excellent", "Good", "Fair", "Marginal" or "Poor" for assessing conditions along Alberta's larger rivers (ie: those with monitoring stations included in Alberta's Long-Term River Network Program). The *Nutrient Index* is a component of the broader Alberta River Water Quality Index (ARWQI) and could provide valuable comparative information if included in a state of watershed report. Because the ARWQI was originally developed for interpreting monitoring data from Alberta Environment and Sustainable Resource Development's Long-Term River Network Program, the applicability of the nutrient index to smaller rivers and streams is problematic, and should be limited to larger rivers where long-term river network data exists.

The River Nutrient Index considers not only total phosphorus and nitrogen, but also pH and dissolved oxygen — two parameters typically monitored in routine sampling — in an annual series of water samples. The Water Quality Guidelines for the Protection of Freshwater Aquatic Life, as set out in *Surface Water Quality Guidelines for the Use in Alberta* (Alberta Environment, 1999), also prescribes objectives for these two additional parameters:

pH	6.5 – 9.0
Oxygen (dissolved)	6.5 mg/L

Similar to the ARWQI, the River Nutrient Index formula incorporates three factors associated with adherence to water quality objectives in calculating an overall score:

- **Scope:** the number of variables not meeting water quality objectives
- **Frequency:** the number of times objectives are not met
- **Amplitude:** the amount by which objectives are not met

The resulting index score is a number between 0 (zero) and 100, where 100 represents the best quality relative to the objectives, and 0 (zero) the worst. The scores are further divided into five categories:

- EXCELLENT (96 – 100) — Guidelines almost always met.
- GOOD (81 – 95) — Guidelines occasionally not met, but usually by small amounts; threat to quality is minimal.
- FAIR (66 – 80) — Guidelines sometimes exceeded by moderate amounts; quality occasionally departs from desirable level.
- MARGINAL (46 – 65) — Guidelines often exceeded, sometimes by large amounts; quality is threatened, often departing from desirable levels.
- POOR (0 – 45) — Guidelines almost always exceeded by large amounts; quality is significantly impaired and is well below desirable levels.

River Nutrient Index scores can be used to track changes in water quality at a given site over time and can also be used to directly compare sites that incorporate these same variables. Although Table 1 presents an annual record of the broader ARWQI scores, the same format could be utilized to illustrate annual nutrient index scores for a river and/or reaches thereof (the same could also apply to any or all of the other three sub-indices included in the ARWQI).

Table 1: Annual Record of Alberta River Water Quality Index Scores (Government of Alberta, 2010).

Alberta River Water Quality Index — 2007 – 2008

Previous years

	96/97	97/98	98/99	99/00	00/01	01/02	02/03	03/04	04/05	05/06	06/07	06/07
OLDMAN RIVER												
Upstream of Lethbridge (Hwy 3)	78	83	88	97	95	96	77	90	96	73	93	94
Downstream of Lethbridge (Hwy 36)	87	84	80	86	91	95	75	89	94	72	92	87
BOW RIVER												
Upstream of Calgary (Cochrane)	96	100	97	97	99	100	100	98	100	100	100	87
Upstream of Calgary (Carseland Weir)	76	87	82	84	89	86	92	90	89	77	84	87
RED DEER RIVER												
Upstream of Red Deer (Ft. Normandeau)	76	n/a	83	87	90	91	95	94	93	80	85	78
Upstream of Red Deer (Morrin Bridge)	86	n/a	80	75	86	93	90	89	89	85	73	83

Excellent	Good	Fair	Marginal	Poor
96-100	81-95	66-80	46-65	0-45

If, however, the objectives used in calculating the index values were to differ between reaches or watersheds, it would then only be possible to compare these sites as to their ability to meet the relevant objectives. For example, in calculating individual nutrient index scores for two sites, each with its own set of nutrient objectives, the same concentration may derive different scores, or alternatively, different concentrations may score the same.

Proper application of the River Nutrient Index requires water quality data derived from a sequential series of monitoring events over the full course of the year, and should not be applied where monitoring may have only been seasonal. As with any other indicator of water quality, this index is susceptible to fluctuations in precipitation. Greater amounts of precipitation may result in elevated surface runoff, which tends to collect and deposit contaminants in receiving waters. Higher annual or seasonal rainfall in some watersheds may lead to an influx of nutrients and a decline in nutrient index score. To further assist in identifying the impact of precipitation and runoff events, one should also report on each of the other metrics incorporated into the index (i.e., total phosphorus (TP), total nitrogen (TN), dissolved oxygen (DO), and pH).

Trophic Status — Lakes

The water quality of a lake is often considered to be an indicator of conditions and pressures within its watershed. Three parameters typically reported on in terms of lake nutrient concentrations are chlorophyll-a, total phosphorus, and secchi depth. Annual reporting of these parameters such as in Figure 1 may illustrate relative difference in water quality between sites and over time.

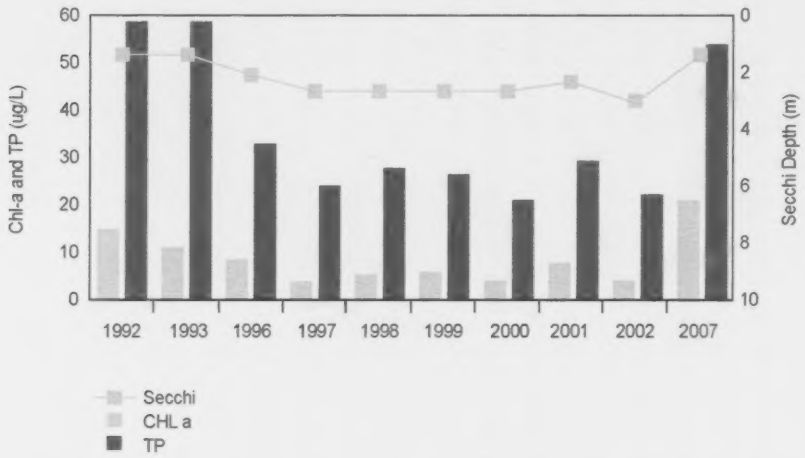


Figure 1: Average Open-water Secchi Depth and Concentrations of Chlorophyll-a and Total Phosphorus — Alix Lake, May to September (Government of Alberta, 2011)

Trophic status, a common indicator of a lake's overall condition, represents the level of a lake's productivity or fertility and is typically determined based on algae production, as represented by the concentration of chlorophyll-a in water samples.

Lake trophic status categories are as follows:

- **Oligotrophic** — low productivity, <2.5 µg/L CHL a
- **Mesotrophic** — moderate productivity, 2.5 – 8 µg/L CHL a
- **Eutrophic** — high productivity, 8 – 25 µg/L CHL a
- **Hypereutrophic** — very high productivity, >25 µg/L CHL a

The assessment of the condition of a lake's watershed, or the condition of a number of lakes within a larger watershed, should consider including annual trophic status as presented in Table 2.

Table 2: Annual Lake Trophic Status — Alix Lake 1992 – 2007 (Government of Alberta, 2011)

	Lake Trophic Status									
Lake	1992	1993	1996	1997	1998	1999	2000	2001	2002	2007
Alix Lake	14.9	11.7	8.5	4.3	5.8	6.2	4.5	8.0	4.2	21.3

Oligotrophic (<2.5 µg/L)	Mesotrophic (2.5 – 8 µg/L)	Eutrophic (8-25 µg/L)	Hypereutrophic (>25 µg/L)

3.1.2 Bacteria Concentrations

Rivers and lakes are important sources of water for agricultural use and are popular for recreational activities. Bacterial contamination of these water bodies could ultimately pose a risk to human, animal, and ecosystem health. Although not all bacteria are harmful to humans, their presence does indicate that harmful, disease-causing bacteria and protozoa may be present.

Coliforms, are a broad class of bacteria that include fecal coliforms, as well as other bacteria that naturally occur in soil and water. For this reason, total coliform counts do not provide a reliable indicator of fecal contamination (the primary concern for human use of untreated surface water). Furthermore, although fecal coliforms represent fecal contamination, not all bacteria in this groups cause gastrointestinal illness in humans. For this reason, measures of *E.coli* are now considered to be one of the best indicators of the human health risk from contact or consumption of untreated surface water.

Single Metric Indicators

Together, fecal coliforms and *E.coli* are the two most commonly tested fecal bacteria used in assessing the health of a water body and its watershed. *Surface Water Quality Guidelines for Use in Alberta* (1999) sets out use-specific surface water quality guidelines for each of these indicators. Elevated levels can result in restrictions on the use of these water bodies.

Guidelines for direct contact recreation

Fecal coliforms	200 cfu / 100 mL
E.coli	200 cfu / 100 mL

Guidelines for irrigation water

Fecal coliforms	100 cfu / 100 mL

Guidelines for drinking water

Fecal coliforms zero (ie: acceptable level = 0 cfu / 100 mL)

Watershed organizations may have further categorized bacteria concentrations as being high/medium/low, or good/fair/poor, but as is the case for nutrient concentrations, the Government of Alberta has not endorsed this type of rating system for bacteria concentrations. Any assessment of bacteria concentrations should compare measured levels to provincial and national water quality guidelines for the specific uses of water within that water body or watershed. Watershed groups wishing to further provide a value statement to the results of a bacteria monitoring program may consider a rating system based on the number of exceedances measured over a one year period for that indicator, as presented for nutrient concentrations in Section 3.1.1.

Bacterial Index — Large Rivers Only

Along with the previously described River Nutrient Index, the Bacterial Index is a component of the broader ARWQI developed by Alberta Environment and Sustainable Resource Development. The Bacterial Index evaluates bacterial densities through an annual series of water samples from which fecal coliforms and *E.coli* concentrations are measured and compared to established water quality guidelines.

The thresholds to be used in calculating the index are as follows:

Fecal coliform	> 100 cfu/100 mL
E. coli	> 100 cfu/100 mL

Similar to the ARWQI and the River Nutrient Index, the Bacterial Index formula incorporates scope, frequency, and amplitude of departures from water quality objectives to derive an index score between 0 (zero) and 100 that follows the same score ranges and categories outlined for the River Nutrient Index.

Decreases in bacterial index ratings tend to be linked to levels of precipitation and associated surface runoff. Increased runoff will generally lead to lower index ratings.

3.2 Surface Water Quantity

In contrast to the many guidelines set out for water quality, few established guidelines exist for water quantity. In some watersheds, flow objectives have been established for either ecological, social, economic or other reasons; however, for the most part there are no defined thresholds for quantity of water in these systems. Flows may fluctuate considerably from one season to the next, and from one year to the next, both naturally and due to anthropogenic uses of the resource.

3.2.1 Licensed Allocations

Having a clear understanding of the volume of surface water allocated for withdrawal from a particular water body or within a watershed is an important piece of information. Current water allocation data is based on volumes identified in water licenses issued under the provincial *Water Act*. Although allocations do not always reflect actual use or consumption of water, reporting on the total volume of licensed allocations over time will provide an indication of the demand for water within a watershed.

Licensed allocations are recorded by use (municipal, agricultural, commercial, industrial, etc.) and as such, groups might consider illustrating allocation by sector. As presented (although provincially) in Figure 2, available historic records can also be used to illustrate changes in demand within a watershed over time (that is, consecutive five or ten year periods). Watershed groups should work through their regional Alberta Environment and Sustainable Resource Development contacts to access this information. Caution needs to be exercised to ensure that only current licenses are included in such an assessment.

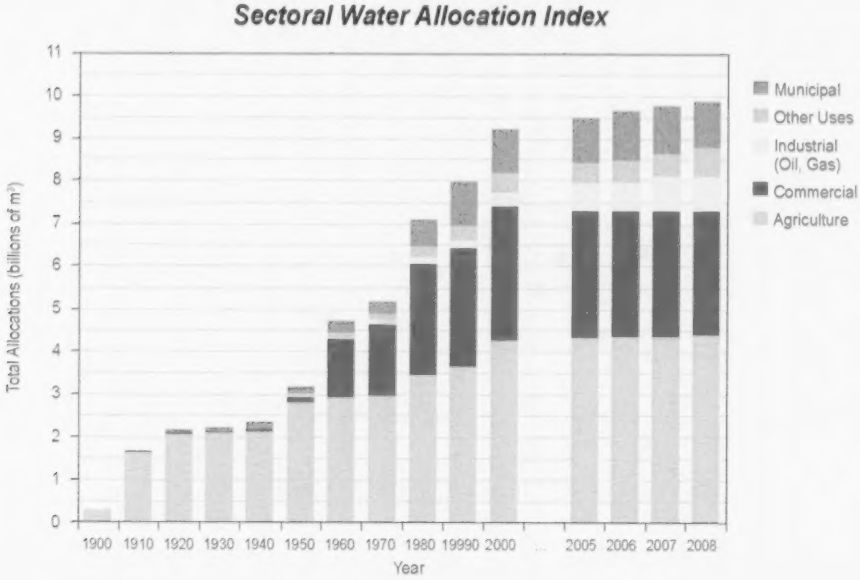
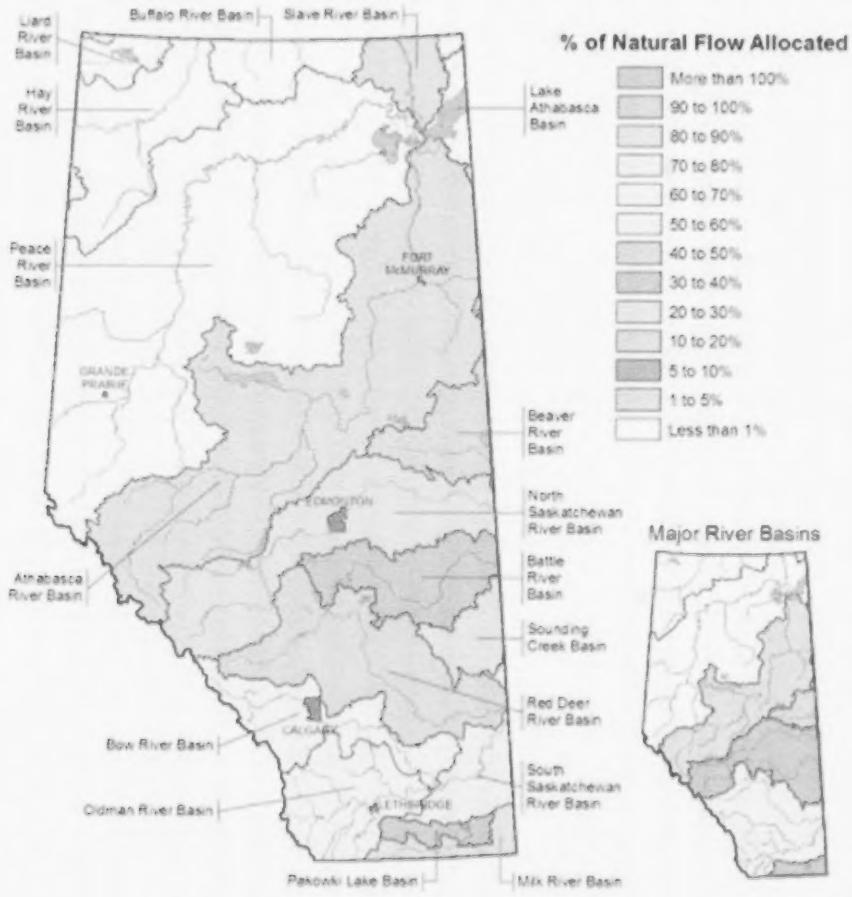


Figure 2: Licensed Water Allocations over Time (Government of Alberta, 2010)

It is important to consider that a volume of allocated water on its own does little to put into perspective the overall impact or pressure upon the resource. Even reporting on the change in volume of water allocated over time does not provide any information on the relationship between the volume of water allocated and the source. More informative is the ability to report on the volume of licensed allocations as a portion of the total volume of surface of water present or available for allocation within that watershed (see Figure 3, although again illustrated at a provincial level, the same format could be applied at a watershed or sub-watershed scale).

Allocations in 2008 by River Basin Compared to Average Natural Flow



Note that allocations do not represent actual water use - only the maximum amount that can be used under the terms of a license. For further explanation please refer to the text in the section "Why is it important?"

Figure 3: Licensed Allocations Compared to Average Natural Flow (Government of Alberta, 2010)

Figure 3 shows the extent to which surface water resources are currently allocated, and provides information on the intensity of water allocation at a watershed level. Reporting on the status of a water body as being a certain percentage allocated (e.g., 70 per cent) increases awareness of the status and sustainability of the resource, and provides the context necessary for making management decisions. To do so requires knowledge of the volume of water within or flowing through that watershed. On rivers and streams, annual volumes can be calculated wherever a monitored gauging station exists. Water Survey of Canada and Alberta Environment and Sustainable Resource Development collectively operate nearly 500 gauging stations across the province; online flow data is available from either Alberta Environment and Sustainable Resource Development's *River Flows and Levels database*; or Environment Canada's *Water Survey of Canada Hydrometric Data database*.

For lake watersheds, technical modeling is required to calculate average annual volumes; however, if a water balance model has recently been developed for the lake, then this information would be readily available.

3.2.2 Variations in Annual Flow and Lake Levels

Historical Lake Level Index

Monitoring of lake levels over time can assist the interpretation of related observed changes in water quality, fisheries, or recreational opportunities. This information can also influence management decisions related to the potential for flooding or water use needs.

Alberta Environment and Sustainable Resource Development's Historical Lake Level Index compares water levels throughout the year to historical patterns in recorded data. For each year, this information is ranked based on five possible categories, ranging from the highest classification of "much above normal" to the lowest, "much below normal". The index is intended to reflect the environment's response to natural fluctuation in climate or changes in water management.

Table 3: Example of Historical Lake Level Index Rankings (Government of Alberta, 2010)

	Ranking of Annual Lake Levels							
Lake	2001	2002	2003	2004	2005	2006	2007	2008
1) Babtiste Lake	below normal	normal	below normal	normal	below normal	normal	Above normal	below normal
6) Cooking Lake	below normal	much below normal	much below normal	much below normal	much below normal	much below normal	much below normal	much below normal
7) Fawcett Lake	below normal	much below normal	normal	normal	normal	normal	normal	normal

Due to the extensive data requirements needed to calculate accurate historical lake levels, applicability of this index is very limited, and should not be considered for lakes other than the 27 listed on Alberta Environment and Sustainable Resource Development's *State of the Environment — Status of Alberta Lake Levels website* for which lake level index rankings are regularly calculated.

River Flow Quantity Index

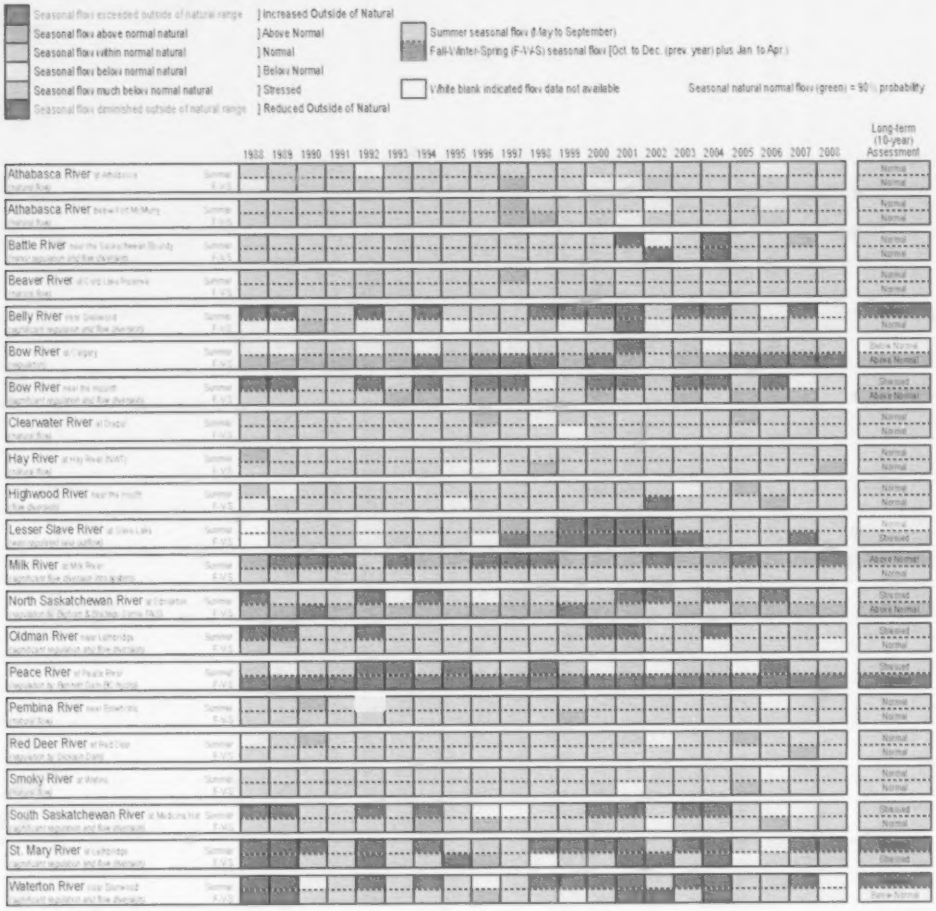
Despite the natural highly variable nature of river flows, determining how much water is flowing down the river, and when, is an important step towards understanding other water-related issues, including the sustainability of fisheries and/or other aquatic species and their habitats, sustainability of riparian areas, and natural in-stream geomorphic processes such as river channel erosion and deposition.

Alberta's River Flow Quantity Index (ARFQI) illustrates the difference between the calculated average natural flow regime (i.e., the quantity and timing of stream flow under what would be natural free-flowing, non-managed conditions) of a river and the actual flows recorded in a managed (i.e., human-modified or stabilized) river system during the year. Flow regimes are examined on a two-season basis with summer open water (May to September) considered as one season and the remaining seven months (October to April) considered the other season. The annual assessment of flow conditions is reported along with a ten-year average, as an indication of potential long-term or cumulative stress.

The ARFQI is based on the assumption that even in a managed system, a natural average flow regime can be expected to occur about 90 per cent of the time. During the other ten per cent of the time, the observed river flow regime will be at an above average or below average state. Although natural ecosystems require variability in flow to support long-term health, more regular observations of above average or below average conditions in managed rivers may indicate that the river is subject to more extreme conditions and stress. Should extreme conditions persist — as a result of exceptionally low flows or unnaturally sustained high flows — one could expect to see changes to the existing ecosystem.

Table 4: Example of Annual Alberta River Flow Quantity Index (Government of Alberta, 2010)

Annual Alberta River Flow Quantity Index: 1988 – 2008 Historical Summary


Seasonal flow exceeded outside of natural range
Seasonal flow above normal natural
Seasonal flow within normal natural
Seasonal flow below normal natural
Seasonal flow much below normal natural
Seasonal flow diminished outside of natural range
] Increased Outside of Natural
] Above Normal
] Normal
] Below Normal
] Stressed
] Reduced Outside of Natural
Summer seasonal flow (May to September)
Fall-Winter-Spring (F-W-S) seasonal flow (Oct. to Dec. (prev. year) plus Jan. to Apr.)
White blank indicated flow data not available
Seasonal natural normal flow (green) = 90% probability
1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008
Long-term (10-year) Assessment
Athabasca River
Athabasca River
Battle River
Beaver River
Belly River
Bow River
Bow River
Clearwater River
Hay River
Highwood River
Lesser Slave River
Milk River
North Saskatchewan River
Oldman River
Peace River
Pembina River
Red Deer River
Smoky River
South Saskatchewan River
St. Mary River
Waterton River

Due to the intensive data requirements needed to calculate an accurate range of average flows, this index should not be applied to any site with less than 30 consecutive years of flow data. Ideally, 50 years of data is recommended. Fortunately, many Water Survey of Canada gauging stations in Alberta have historical flow records dating far enough back to extend the use of this index beyond the 21 stations listed above in Table 4. Although the ARQFI could be applied at any watershed scale, it is expected to breakdown when applied to smaller tributaries due to the greater variability in stream flow characteristic of these smaller streams. After all, it may not be uncommon or unnatural for a smaller stream to go dry at certain periods.

3.2.3 Flow Commitments

Water Conservation Objectives

As outlined in Alberta's *Water Act*, a Water Conservation Objective (WCO) relates to the volume and quality of water to remain in a river for the protection of that natural water body and its aquatic environment. They may define a minimum rate of flow as either a fixed value, or as flow target that fluctuates throughout the season so as to mimic flows. In most cases, the outcome is a balance between leaving water in the river for the environment and diverting it for use. The establishment of a WCO does not guarantee the desired amount of water will flow in the river. WCOs are flow targets under the priority water allocation system.

These volumetric targets do not exist for all water bodies, particularly not for smaller rivers or lakes. Where WCOs have been established (e.g., South Saskatchewan River Basin, Cold Lake), state of the watershed reports should consider including the water body's record of meeting these targets on a seasonal, monthly or even weekly basis. Flows (or lake levels) should be reported in relation to the WCO established for that waterbody and the deviations from it (for example, as two different curves on a hydrograph, or as two different lines on a lake elevation graph).

In-Stream Flow Needs

Instream Flow Needs (IFNs) are estimates of minimum flows required to maintain ecosystem components and provide a high level of protection for the aquatic environment over the long term. Although calculated as a threshold, IFN estimates do not establish a commitment of water flow, and are instead intended as information to be used in the decision-making process of establishing of a water conservation objective or other objectives. Although watershed groups may often lean toward reporting on the deviation of a river/

stream/creek's flow from its IFN value, assessments should ideally report on the deviation from the water conservation objective. After all, the water conservation objective is the target that has been set in consideration of society's expectations and desired outcomes for that water body.

3.3 Groundwater Quantity

3.3.1 Groundwater Allocations

Licensed Allocations

The volume of groundwater being withdrawn within a watershed is an important piece of information. However, like surface water, available allocation data is limited to licensed allocations and does not accurately reflect actual usage, nor does it consider unlicensed domestic or household uses. Ideally, it would be useful to relate the volume of groundwater allocated back to the total volume of groundwater available for allocation. Unfortunately, the latter information is not readily available, especially at a watershed level. Alberta Environment and Sustainable Resource Development is however making strides in collecting this data through its Provincial Groundwater Inventory Program. It is also important to note that as aquifers can cross watershed boundaries, this creates an additional challenge for watershed reporting.

In spite of these challenges, groups reporting on the health of their watersheds should consider reporting on cumulative licensed groundwater allocation over time (m^3/yr). Historic records are available and can be used to calculate allocations to illustrate trends over time, such as over consecutive five or ten year periods. Because these records also document water well locations, it is possible to illustrate this information geographically within a watershed (e.g., m^3/yr/TWP). Allocations may be further categorized over a volumetric range, such as that used by Alberta Environment and Sustainable Resource Development in Figure 4. For greater detail at a local watershed scale, these ranges can be broken down into smaller ranges, or presented for smaller parcels of land (e.g., sections rather than townships).

Because groundwater licensed allocations are recorded by use (municipal, agricultural, commercial, industrial, etc.), watershed organizations should consider reporting usage by sector, and illustrate any changes or trends in sector usage over these same time periods.

Although reporting on the change in licensed volume of groundwater allocated over time provides no information on the relationship between the allocated volume and the volume of the source, it does provide an indication of the demand for, and pressure upon the resource.

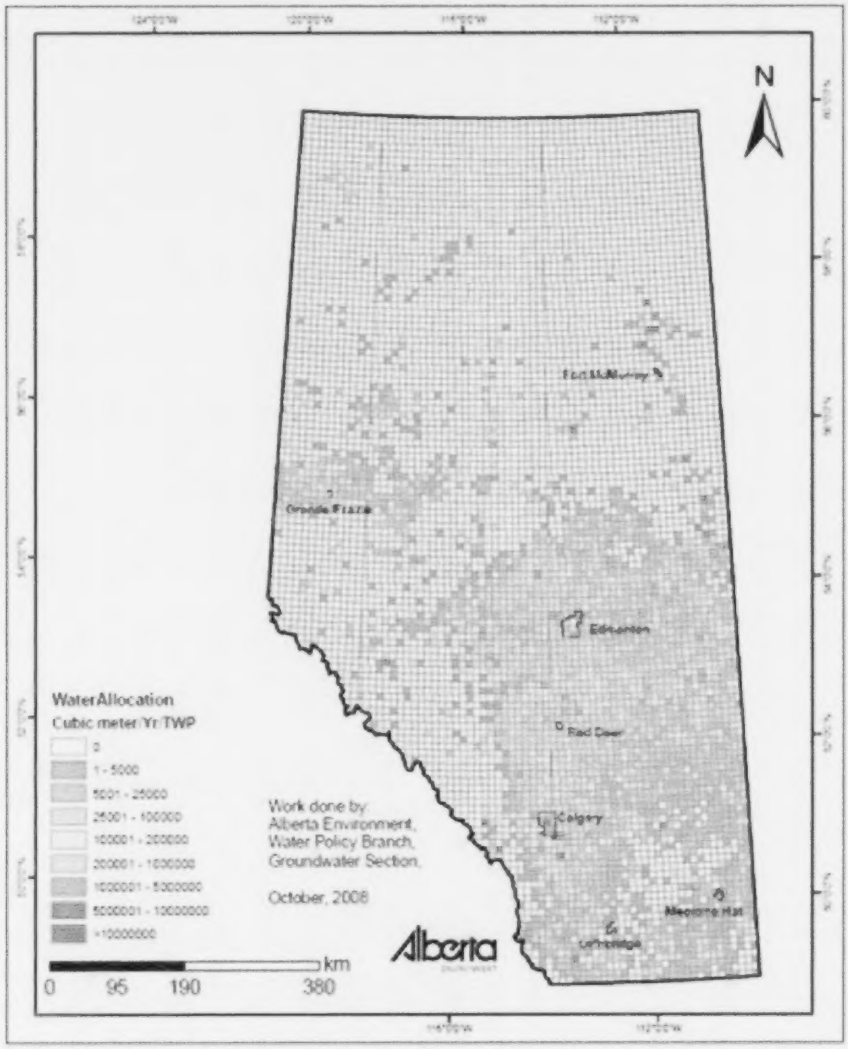


Figure 4: Allocated Groundwater Diversions across Alberta 2008 (Government of Alberta, 2008)

Unlicensed Allocations and Withdrawals

Alberta's *Water Act* stipulates that persons may withdraw up to 1250 m^3 of groundwater per year for domestic or household use without need for a license. This sector represents a large number of users for whom the actual volume of groundwater withdrawal is unknown.

Because of the right to this water, the allowable volume of 1250 m^3/yr per household is considered an unlicensed allocation, and the total unlicensed allocation may be calculated by multiplying the allowable volume per household by the known number of domestic wells. Information on the latter is available from Alberta's water well database. Watershed groups should work through their Alberta Environment and Sustainable Resource Development contacts to access this information. It is recommended that only wells that are 20 years old or less be selected for such an assessment so as to exclude wells that might now be abandoned.

Although 1250m^3/yr represents a plausible maximum usage scenario, it has been estimated that the actual usage is more in the range of 1000 litres/day or 365 m^3/household/yr (Energy Resources Conservation Board, 2009). As such, a watershed group may wish to use this value to estimate actual usage. Similar to calculating the maximum usage scenario, multiplying the known number of domestic wells (20 years old or less) by 365 m^3/yr provides an estimate of the volume being withdrawn for domestic use.

Similar to the trend assessment performed for licensed allocations, watershed groups may also consider reporting on the cumulative unlicensed groundwater allocation and/or estimated domestic groundwater withdrawal over time.

3.3.2 Groundwater Well Density

Water well density could also be considered an indicator of total licensed and unlicensed water use, and of the potential impact humans are having on the groundwater resource. Although, this number provides no measure of the actual or authorized withdrawal of water from the aquifer, it may reflect the intensity of the pressure upon the resource. Alternatively, it may reflect the availability and/or suitability of groundwater in particular areas of the watershed. Either way, watershed groups should consider reporting on changes in water well density over time. Historic cumulative snapshots of groundwater well density may further illustrate areas within a watershed undergoing higher levels of development, which could inform the selection of target areas for management activities or programs.

Areas with a greater number of wells may also hold a greater number of unused or abandoned wells, and thus serve as an indicator of the potential contamination risk to the groundwater source. For this reason, any assessment of groundwater well density should not be limited to wells less than 20 years old and should include all known wells. One should keep in mind that mandatory reporting of water well drilling was only introduced in the late 1970s, and as such, historical records earlier than 1980 may not be complete.

Again in this case, townships provide a good spatial unit for reporting on the number of known water wells, and Alberta Environment and Sustainable Resource Development has an established classification of ranges for illustrating the distribution of water wells in Alberta (See Figure 5). For greater detail at a local watershed scale, parcels of land smaller than a township could be considered.

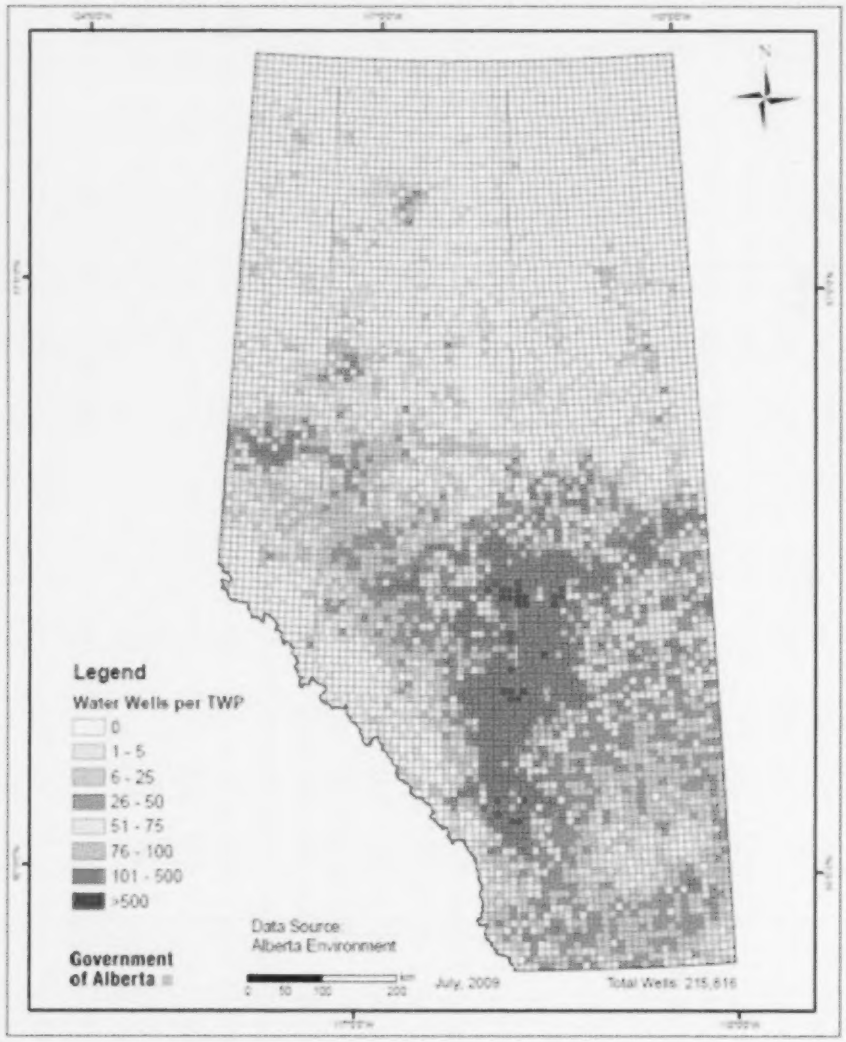


Figure 5: Distribution of Water Wells in Alberta (Government of Alberta, 2009)

3.4 Landscape

3.4.1 Land Use/Land Cover

The intensity of land use and the associated land cover types across a watershed influence water supply and quality, as well as aquatic, riparian, and upland ecosystem health. Changes in land use patterns reflect trends in human development, such as forested land being converted to agriculture, and agricultural lands lost to urban sprawl. Land use may further provide an indication of potential pollutant sources within the watershed.

Table 5: Typical Land Use and Land Cover Categories

Land Use	Land Cover Category
Natural areas	• Water bodies/wetlands • Coniferous forest • Deciduous forest • Mixed forest • Shrubland • Grassland
Agricultural lands	• Annual cropland • Perennial cropland and pasture • Rangeland
Industrial areas	• Non-vegetated/barren land • Forest clear-cuts
Urban/residential	• Urban residential development/settlement • Non urban residential development (country residential)
Other	• Roads and rail lines • Other

Because land use changes as development progresses, one of the simplest indicators of the pressures upon a watershed is the amount of landscape disturbance occurring relative to the size of the basin. In general, the more land is developed (i.e., converted from its natural state), the more likely it is that natural watershed functioning will be negatively impacted. The extent, density, and location of different disturbances, land uses, and associated land cover types can reflect pressures upon the natural landscape.

For the most part, aside from within the boundaries of some larger urban jurisdictions (e.g., City of Calgary, City of Edmonton), thresholds and/or targets for particular land uses have typically not been set. This is not to say that they could not be, and may in fact be addressed through regional land-use plans or environmental management frameworks.

Evaluating land use distribution and change also facilitates the targeting of future implementation efforts because some management practices are most effective when applied to a particular land use.

Linear Disturbance

Linear features such as roads, power transmission lines, seismic lines, and pipelines create new corridors that influence human and animal movement patterns, and can alter local hydrology. These disturbances are often cumulative and synergistic. Inevitably, if extensive enough, these activities can disrupt the ecological integrity of watersheds and the watercourses that drain them. Quantifying linear disturbance may identify areas where potential changes in water quality and fish and wildlife populations may be impacted.

Throughout the scientific literature are reports of the impact of linear disturbance. Road density thresholds, above which have the potential to negatively affect various wildlife species, have been determined for a variety of species. As an example, the British Columbia Ministry of Water, Land, and Air Protection (2002) affirms the following:

- at road densities of 0.4 km/km^2, grizzly bears are significantly displaced;
- at 0.62 km/km^2, elk are adversely affected; and
- at 1.25 km/km^2, black bears are significantly displaced.

Studies in Alberta (e.g., Ripley et al, 2005) have found a direct negative correlation between bull trout populations and road density. Alberta Environment and Sustainable Resource Development's Fisheries Management Branch has recently developed, as part of its management approach, the following categories of risk to bull trout based on road densities:

- 0.0 – 0.1 km/km^2 – low risk
- 0.1 – 0.2 km/km^2 – moderate risk
- 0.2 – 0.6 km/km^2 – high risk
- 0.6 – 1.0 km/km^2 – very high risk
- > 1.0 km/km^2 – bull trout likely extirpated.

Watershed groups should be mindful of these thresholds if attaching any sort of value statement to measures of linear disturbance within their watershed. For example, rating road densities of 2 km/km^2 (i.e., 2% of watershed area assuming a 10 m wide disturbance area) or less as **good**, 2-3 km/km^2 (2-3% area) as **fair**, and >3 km/km^2 (>3% area) as **poor**, as has been documented in several recent state of the watershed reports produced by watershed groups in Alberta, may not be appropriate in all watershed or sub-watersheds. Groups undertaking these assessments should seriously consider watershed-specific characteristics and objectives, and seek expert advice to assist with selecting measures and thresholds. The map in Figure 6 depicts calculated road densities for Alberta's watersheds based on 2009 road network data.

Reporting on changes in the density of linear disturbance in individual watersheds or sub-watersheds over time may provide further insight into potential or observed changes to water quality and wildlife populations. In addition to serving as a benchmark for future comparison, comparisons between current levels and historical data can be made to estimate the increase in disturbed areas over time. Findings could then be reported graphically, spatially, or in tabular form.

Government of Alberta
Road Density per Tertiary Watershed
0.0 0.1 0.2 0.6 1.0 >1.0
km/km2
Tertiary Watershed Road Density Levels

Figure 6: Density of All Roads by Watershed in Alberta (Government of Alberta, 2011).

3.4.2 Riparian Health

Riparian health assessments and inventories examine vegetative and physical parameters to provide information about the function and condition of a riparian area. These assessments provide comprehensive information about the diversity, structure and health of plant communities within the riparian area along reaches of streams and stretches of shoreline. Evaluating riparian conditions will indicate areas where human activities and/or natural pressures may be impacting watershed health.

Different methodologies have been used in Alberta for assessing riparian health (e.g., on-site biophysical inventories, and aerial videography). Each of these examples consider and weigh different parameters, and have different scoring methods and ratings. As such, different (and sometimes conflicting) conclusions may arise as to an area's riparian health status. This creates challenges in terms of integrating and comparing results. For comparative purposes or for identifying trends over time, only like-methodologies should be considered.

Although repeat monitoring of riparian areas over time is extremely desirable, very few riparian areas within a watershed are ever sampled more than once as the site-selection process is typically project-related. For this reason it is not always possible to deduce trends in riparian health on a site-by-site basis. One way around this is to accept the findings of all riparian assessments undertaken within a set time period (e.g., five years) as being reflective of the overall conditions within that watershed or sub-watershed during that time period. Differences between riparian health scores conducted in different time periods may then be reported as changes in riparian health over time (assuming sufficient information exists).

For example, riparian health scores for all riparian areas assessed from 2006 to 2010 could be compared to scores for riparian areas within the same watershed assessed from 2001 to 2005 (and/or any other five year period), and the differences reported as change over time. This was in fact the approach taken by the Saskatchewan Watershed Authority in their 2007 and 2010 State of the Watershed Reports, and is not unlike trend assessments used for any other parameter. The results can then be presented graphically, spatially, or in tabular form.

Table 6: Theoretical Example of Riparian Health Status of Sampled Sites during Identified Time Periods (using Cows & Fish health assessment categories)

Riparian Health Category	1996 – 2000	2001 – 2005	2006 – 2010
Healthy	36% (4/11)	36% (5/14)	38% (5/13)
Healthy with Problems	36% (4/11)	43% (6/14)	46% (6/13)
Unhealthy	27% (3/11)	21% (3/14)	15% (2/13)

One important consideration is to recognize that although riparian health status may change as a consequence of improvement or deterioration in measured riparian health, status within any time period will also be dependent upon the number and location of sites assessed.

3.5 Biological Community

Biological indicators of aquatic ecosystems are important and provide a direct assessment of resource conditions because biota will often reflect the cumulative influence of all sources of environmental stress.

3.5.1 Biotic Integrity

An Index of Biotic Integrity (IBI) is a multi-metric assessment tool used to describe biological health in terms of ecological structure and function. Unlike chemical testing of water samples, which gives brief snap-shots of chemical concentrations, an index of biotic integrity captures the cumulative impact on the biological community structure and reflects broader ecological conditions.

Originally developed based on assessments of fish populations, more recent indices of biotic integrity have been developed for algae, macroinvertebrates, vascular plants, and even combinations of these. The IBI examines a number of characteristics of the community structure. For example, an index of biotic integrity for a fish community would consider abundance (total number of fish), the diversity (number of different fish species), as well as trophic (food chain) interactions to calculate an index of biotic integrity score.

Because the index compares what is measured at a site with what would be expected *in the absence of human disturbance*, the score can illustrate the impact of anthropogenic activities in the surrounding watershed. Indices of biotic integrity are usually watershed-specific and require experienced professionals to provide sufficient quality data to correctly calculate a score. For this reason, an index of biotic integrity may not be suitable as an indicator in all watersheds, but where the data and expertise are available, the index could provide considerable insight into the overall health of the watershed and its biological community.

Fish Sustainability Index

Developed by the Fisheries Management Branch of Alberta Environment and Sustainable Resource Development, the Alberta Fish Sustainability Index (FSI) is a tool used to bring consistency to individual fish population status assessments across the province. The index provides a standardized approach for evaluating existing data and identifies the types of field data that should be collected in the future to allow for more quantitative assessments. With respect to watershed management, the purpose of the FSI is to:

- Provide a landscape-level, provincial overview of fish sustainability;
- Allow for temporal comparisons in changes in sustainability; and
- Support broad-level comparisons between fish sustainability and management actions (e.g., regulations, or land-use planning).

Each FSI assessment represents a snapshot of the current status of a population of a particular fish species within a designated spatial unit. In essence, it is a "report card' assessment of a focal species status in that area. Typically, FSI assessments are done at the population level, and then may be rolled up to larger scales (e.g., watershed, drainage basin, etc.).

Fish populations are evaluated in terms of four groups of metrics:

- population integrity;
- population productivity;
- threats resulting from people (harvest and habitat loss) and the ability to mitigate those threats; and
- reliability of the data used (timeliness, quantity, quality).

Population sustainability is then ranked against a theoretical population undisturbed by human activity. Differences between measured and theoretical populations are translated to a scale from 1 to 5, with a score of 1 corresponding to a focal population that is least sustainable and very different from the theoretical population, and a score of 5 corresponding to a focal population that is most sustainable and very similar to the theoretical population. Figure 7 is an example of one of the FSI metrics being reported at a population unit and at the watershed scale.

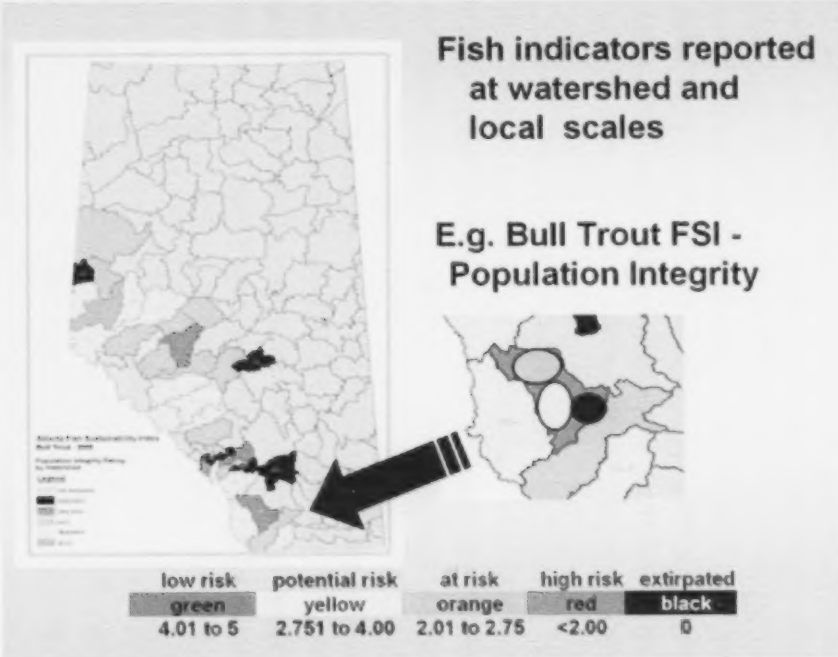


Figure 7: Bull Trout Population Integrity Rating by Watershed. Excerpt from *Fish-based Indicators to Inform Land-use Management in Alberta*, a presentation created by David Park (ASRD, 2009). Note, the inset illustrates that Fish Sustainability Index results at the watershed scale are typically aggregations of scores for individual population units.

The advantage of this tool is that fish sustainability indices may be applied to any scale of watershed, and although each FSI is species-specific, individual indices may be rolled up to provide a collective FSI score for fish species within that watershed. Alternatively, each of the four metric groups used to calculate the index may be looked at separately to assess the status of these factors.

FSI assessments are currently being conducted by Alberta Environment and Sustainable Resource Development for fish species in priority sequence across the province. Watershed groups seeking a not yet completed species-specific FSI assessment for their watershed may contact the local fisheries biologist with Alberta Environment and Sustainable Resources Development to request such an assessment.

Fish Community Index

Data on the presence or absence of individual fish species can also be evaluated to assess relative overall aquatic habitat health, based on individual species tolerance of conditions. In an effort to assess and categorize fish community health in Alberta's rivers and streams, Alberta Environment and Sustainable Resource Development developed the Fish Community Index (FCI) in 2008. A variation of the Index of Biotic Integrity approach, the FCI ranks the health of fish communities along a scale dependent upon the observed community composition. A greater number of fish species sensitive to human disturbance is indicative of a less disturbed habitat. A greater number of resilient species suggests a more disturbed habitat.

Sensitive fish species consist of rare, predatory, and specialist species, whereas resilient species consist of generalist and irruptive species (species that show dramatic population growth in response to ecosystem disturbance). Their presence will vary between ecosystems, as may the ecological classification of species. It is necessary to engage an aquatic ecologist to determine species presence and classify those species.

Fish Community Index Score

= No. of Sensitive Species – No. of Resilient Species

= (rare + apex predators + specialists) – (generalists + irruptives)

The greater **positive** departure from a fish community index score of 0 (zero), the *less* disturbed the aquatic habitat. The greater **negative** departure from a fish community index score of 0 (zero), the *more* disturbed the aquatic habitat (see Figure 8). Associated land use and land cover types further support these conclusions.

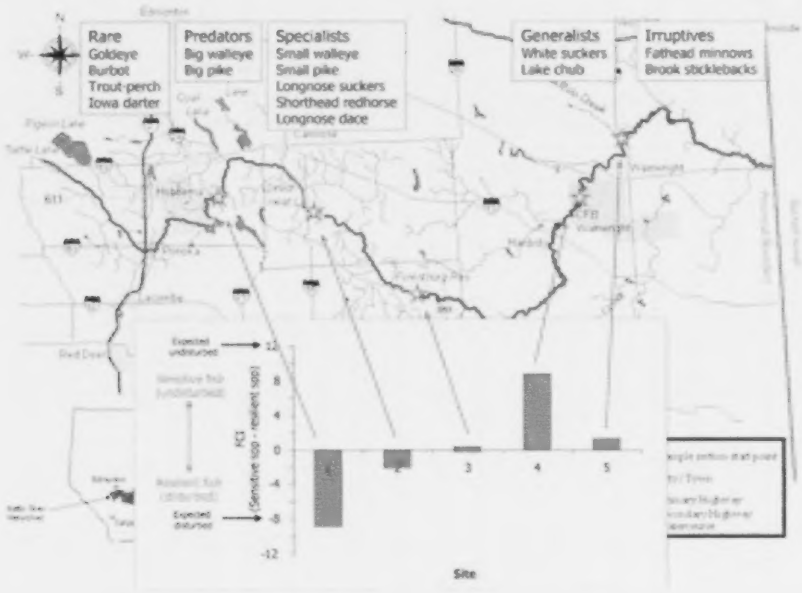


Figure 8: Battle River Fish Community Composition and Index (2010). Excerpt from *The Last Goldeye*, a presentation created by Michael Sullivan (ASRD, 2010)

Because this technique of assessing aquatic habitats considers all species of fish (sport fish or other) residing within the defined watershed unit or water body, the Fish Community Index can only be applied to a reach along a stream or river, or a lake where an inventory of fish species has recently been conducted.

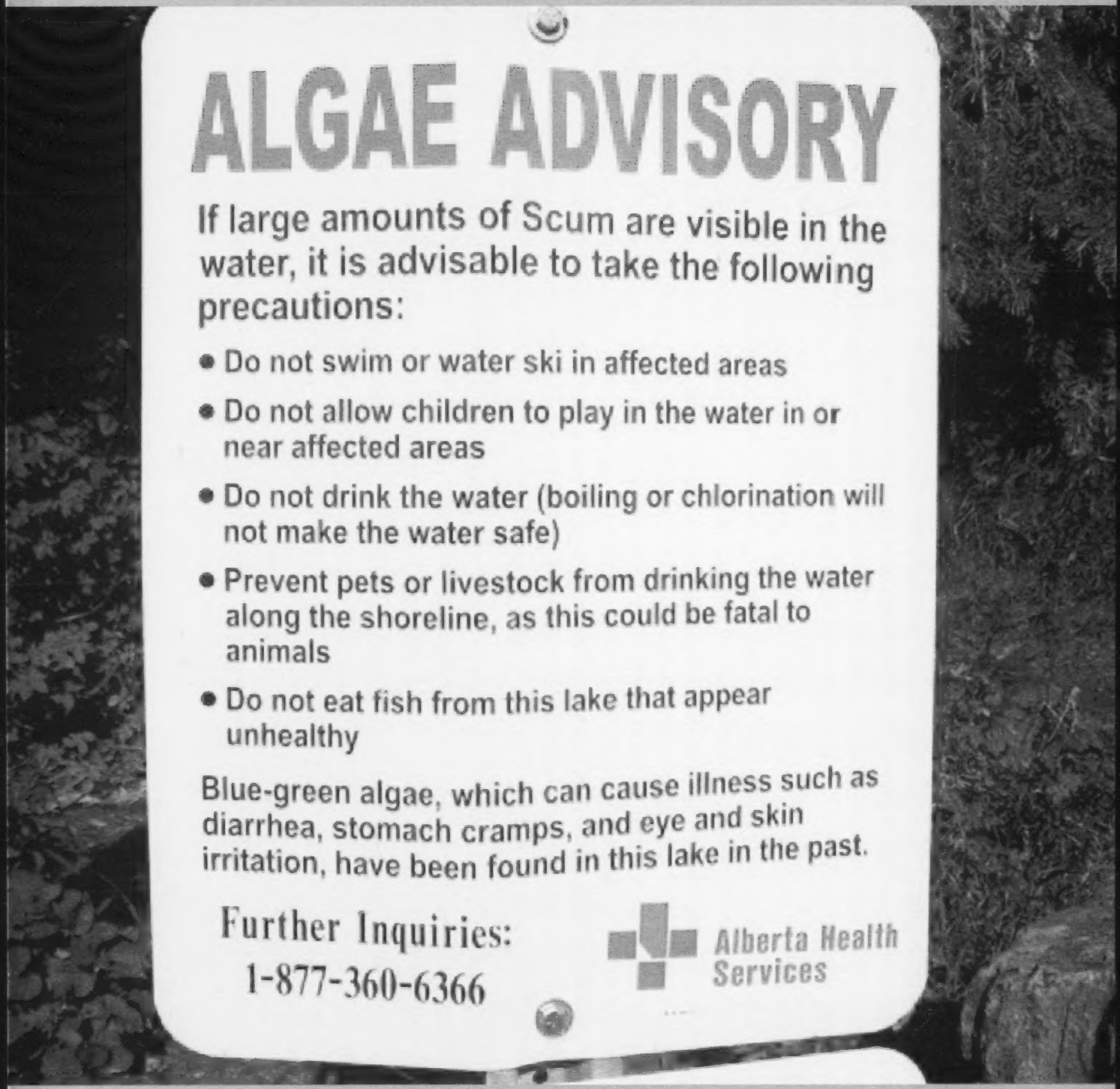

ALGAE ADVISORY
If large amounts of Scum are visible in the water, it is advisable to take the following precautions:
• Do not swim or water ski in affected areas
• Do not allow children to play in the water in or near affected areas
• Do not drink the water (boiling or chlorination will not make the water safe)
• Prevent pets or livestock from drinking the water along the shoreline, as this could be fatal to animals
• Do not eat fish from this lake that appear unhealthy
Blue-green algae, which can cause illness such as diarrhea, stomach cramps, and eye and skin irritation, have been found in this lake in the past.
Further Inquiries:
1-877-360-6366
Alberta Health Services

photo credit: Alberta Environment and Sustainable Resource Development

4.0 Conclusion

It is important to recognize that the indicators presented in this guide do not represent all of the environmental parameters that may be considered and reported on for a watershed. Rather, they likely reflect but a fraction of the indicators associated with the many health and management questions that may arise in any particular watershed. Careful thought and consideration should be given to those parameters that when reported on and measured over time, will support long-term management objectives and desired outcomes for a given watershed.

Many watershed organizations have already prepared informative state of the watershed reports for their watershed. These reports provide excellent examples of the variety of indicators that may be included in an assessment of watershed health and should be referred to throughout the indicator selection process.

Achieving consistency in the manner in which these indicators are reported on in future state of the watershed reports (the aim of this document) is not about restricting what groups choose to include or report on in these reports. Consistency in the format in which the information is presented will further facilitate comparative and collective assessments of the health of Alberta's watersheds, provide the guidance that watershed groups have been asking for, and allow the information contained within these assessments to be more effectively used in the larger arena of Alberta's planning and management system.

photo credit: Travel Alberta

Appendix A: Acknowledgements

Alberta Environment and Sustainable Resource Development would like to acknowledge the many representatives of Alberta's watershed stewardship community, Watershed Planning and Advisory Councils, and the Government of Alberta staff who attended and provided input during the workshops held early in the process of selecting these common indicators. We also wish to acknowledge the initiative these groups took in creating State of Watershed reports, and providing a learning platform that greatly informed the development of this guide.

photo credit: Alberta Environment and Sustainable Resource Development

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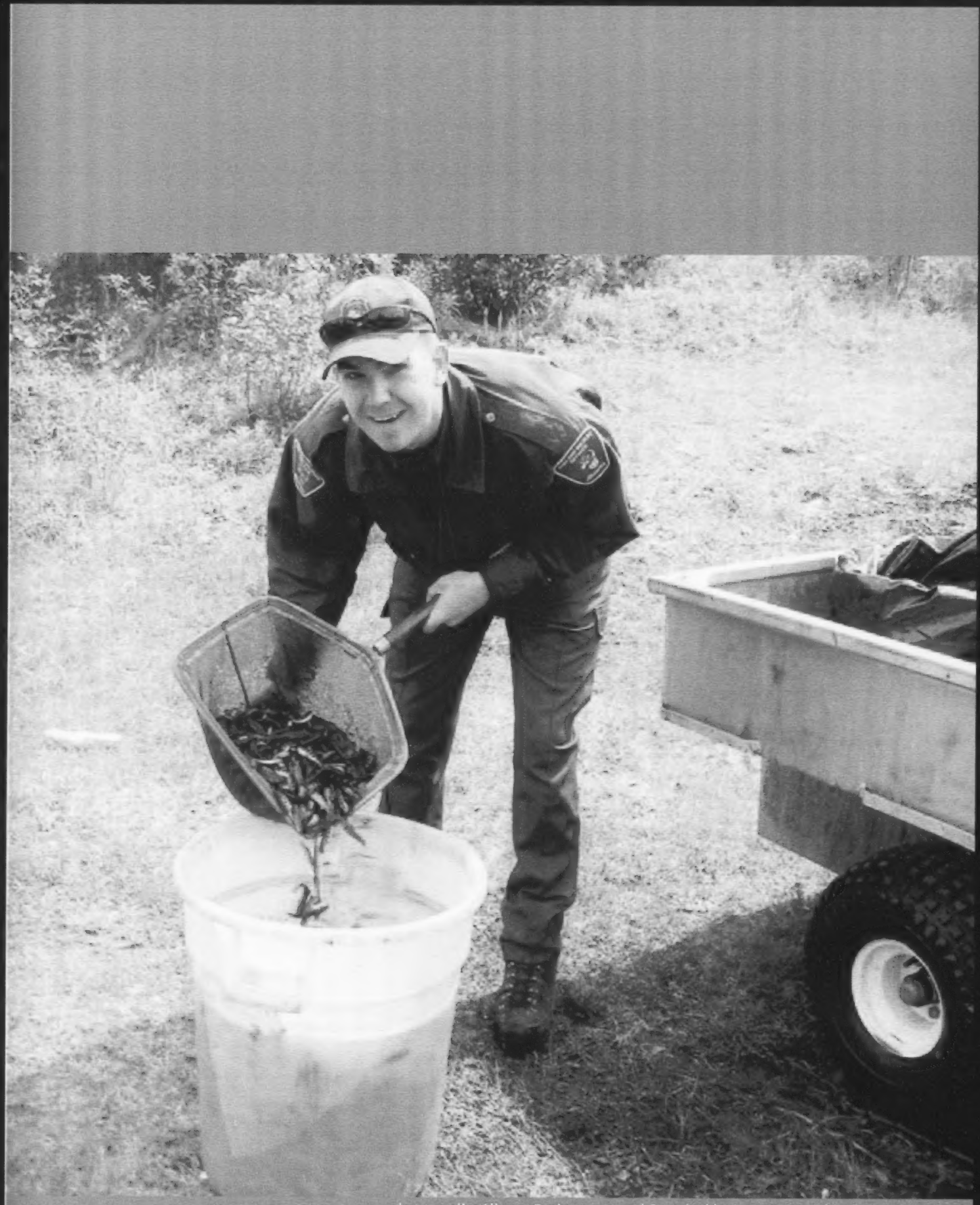

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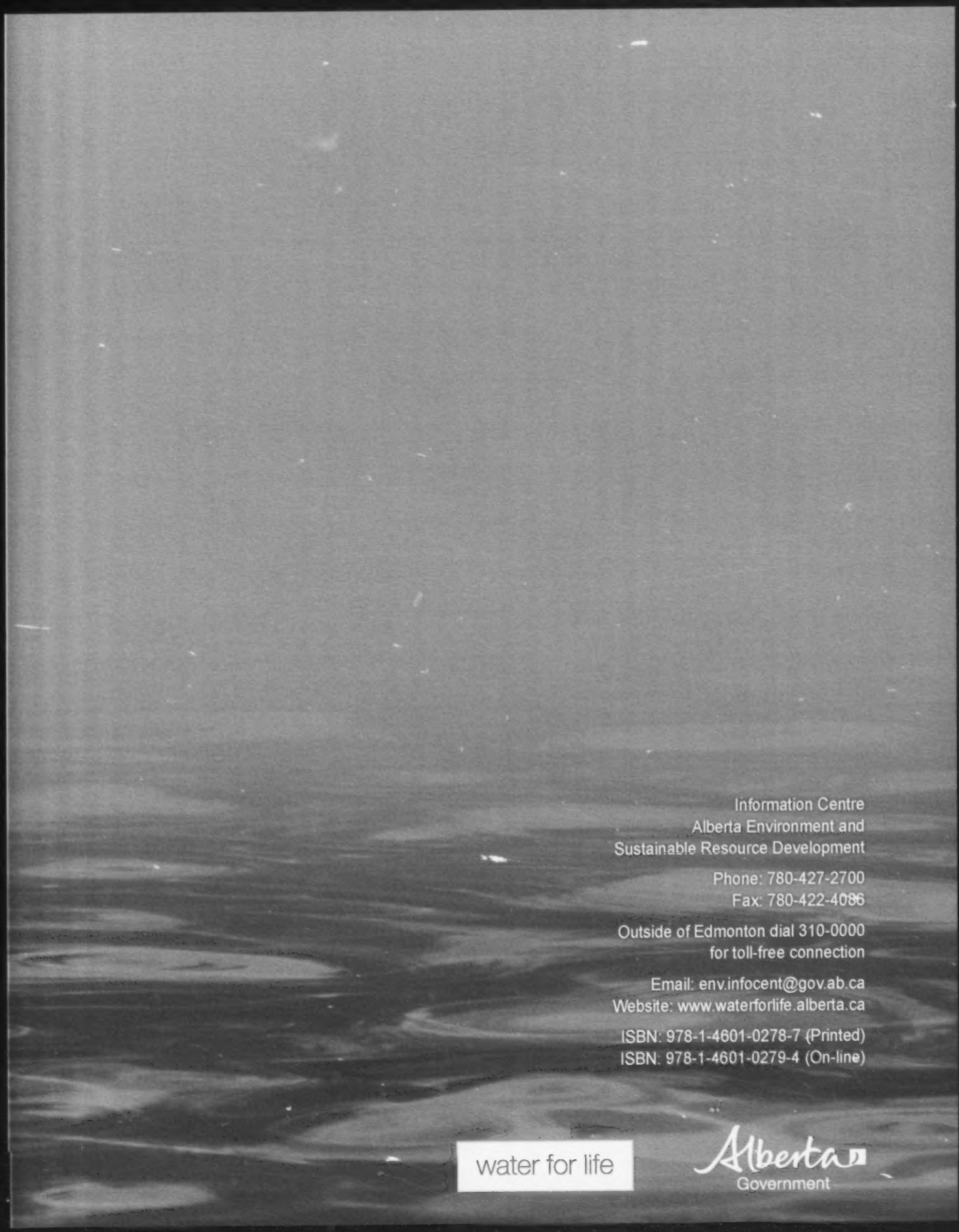

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